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The term "agricultural social sciences" is introduced and refers to the areas of agricultural economics, rural sociology, agricultural business, farm and ranch management, and agricultural administration. The report discusses the colleges of agriculture of the future, the college students of the future, and the future agricultural social scientist and his educational needs. These needs are discussed in terms of biological and physical science, and mathematics. Minimum recommendations in mathematics include concepts in calculus and probability statistics. The report emphasizes undergraduate training, but also discusses Masters and Ph.D. level training. (BC)

Report of the

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FOREWARD

In 1965 the Commission on Undergraduate Education in the Biological Sciences (CUEBS) established a Panel on Preprofessional Training in the Agricultural Sciences (PPTAS) to consider the following questions:

(1) What preparation in basic biology, physical sciences and mathematics is desirable for students planning careers in the agricultural sciences?

(2) To what extent can agricultural curricula include the same biology core program taken by other biological science majors?

The panel early recognized that it would be an Herculean task to evaluate adequately all the implications involved in the questions posed, especially when students in such divergent areas (e.g., forestry, wildlife, food science, agricultural engineering, preveterinary medicine) were to be considered. In an effort to obtain the broadest thinking possible, six action committees composed of scientists from universities throughout the country were created in cooperation with the Commission on Education in Agriculture and Natural Resources (CEANAR). Each action committee considered one of the following areas: animal sciences, plant and soil sciences, natural resources, food sciences, bioengineering, social sciences; and each was charged with the responsibility for studying and recommending desirable preparation in the biological sciences and cognate disciplines for undergraduates majoring in the committee's area of specialization. The committees were asked to think in terms of requirements for students who will be professional scientists and agricultural production workers in the 1980's.

The following report is from one of the action committees. The ideas expressed in the report are those of the action committee members and not necessarily those of either of the sponsoring Commissions. The PPTAS position paper itself is available as CUEBS Publication No. 17.

Martin W. Schein
Director, CUEBS

INTRODUCTION

In this report the term agricultural social sciences refers to areas of study such as those now labeled agricultural economics, rural sociology, agricultural business, farm and ranch management, agricultural administration, etc. Overall, the agricultural social scientist is one whose specialization focuses on those social and economic problems associated with rural areas and the production, processing and distribution of biologically derived commodities and related services (e.g., outdoor recreation). The term biological science includes topics which are generally considered biological irrespective of the instructional unit offering the course. Many courses offered in "agriculture" are applied biology; so are some behavioral courses in psychology.

The instruction to disregard current limitations was acceptable with regard to all factors other than time limits. Inasmuch as the charge specifically referred to undergraduate students, we considered it necessary to recognize the cost of courses not taken as well as the benefits of courses included in the program. While additional work in many areas would provide a better education, it is necessary at some point to restrict the total course work available to what will fit an undergraduate's four year program. Our restriction required that we implicitly consider the total curriculum pattern of the undergraduate student. We have avoided spelling out a total curriculum, but do recognize that our recommendations reflect an underlying assumption regarding the amount of time available for the biological sciences. We have deliberately avoided stating a precise allocation for biological sciences because of the difficulty in defining where biology ends and another discipline begins.

We recognize that an important reciprocal task exists--to recommend the social sciences important in the education of agriculturalists and biologists. While such social science education is vital, its delineation was outside our charge. Also outside our charge was the recommendation of social science for the agricultural social science major.

Our recommendations look forward to the needs of man in the 21st century when he inhabits a universe with human life on several planets. We must view the world in this way in order to arrive at a realistic curriculum for our undergraduate students in the 1970's. We recognize that the recommendations embodied in this report are not likely to be implemented in most institutions prior to 1970. The first graduate of this program would be forthcoming about 1974 and would be only 47 years old in the year 2000. Thus, as our initial graduates approach the peak of their productive lives, they will live and work in a world very different from that of today.

We also recognize that national committees can provide only an initial impetus for curricula development at any specific educational institution. Each institution has limitations imposed by the available faculty, facilities and funds. That some institutions will find our recommendations completely unacceptable will not surprise us.

That no institution totally accepts our recommendations will not surprise us. We only hope that our recommendations and the reasons behind them are of sufficient value to warrant careful consideration by every institution as it proceeds with its regular review of courses and curricula.

COLLEGES OF AGRICULTURE OF THE FUTURE

Agriculture is currently offered at a number of colleges and universities--both Land Grant and non Land Grant. The non Land Grant schools emphasize the teaching function and commonly have a small portion of their budgets devoted to research and off campus teaching. In contrast, the Land Grant schools typically have a larger portion of their budgets devoted to research and extension activities than to teaching. Further, the teaching effort at non Land Grant schools generally is heavily concentrated at the undergraduate level whereas Land Grant schools also educate large numbers at the graduate level.

Basic research has received increased emphasis at the Land Grant schools as non campus (public and private) research centers conduct an increasing proportion of the applied research. Because of the increased sophistication and specialization of their research, it is not clear that undergraduate curricula organization and research organization, will, or should, be identical in Land Grant Colleges of Agriculture. A move is now underway in some colleges to establish generic curricula in areas such as plant science, animal science, agricultural social science, etc.

The implications of these trends for undergraduate training in the Land Grant Colleges of Agriculture are still unclear. We suspect, however, that undergraduate curricula will be increasingly torn between the service of two masters. On the one hand, the research groups will be highly concerned about developing undergraduates who are well prepared for graduate training in either a basic or applied discipline. On the other hand, agricultural industry groups, extension personnel, farm organization leaders, and others may emphasize the need for educating men and women who will join the agricultural industry at the B.S. degree level.

These differences have become apparent in a number of colleges. What is less apparent is the way these differences are sometimes manifest in curricula decisions--the narrowness of some "science" curricula and the scientific shallowness of some "general" curricula.

These differences have led, in a number of colleges, to dual curricula. One side of the dual emphasizes graduate preparation with less concern for direct applications to agriculture or agri-business. The other side of the dual is for students whose terminal degree is the B.S. or M.S. Their curricula places greater emphasis on agricultural applications and agri-business courses. These students may be assigned a second class status by the university faculty, yet some become leading farmers,

agri-businessmen and farm organization leaders after graduation. Protecting the image and the quality of this program while challenging the potential Ph.D. poses a real challenge for the educational organization of Colleges of Agriculture. We recognize that the solutions to this dilemma will vary from state to state. Some universities may limit entrance to those believed potentially capable of Ph.D. level study. Other schools may educate the terminal B.S. or M.S. student. Other Colleges of Agriculture must try to serve both roles.

THE COLLEGE STUDENTS OF TOMORROW

We assume that secondary and elementary education will continue to strive for improvement. Major progress has been made in improving training in mathematics and science, especially since the Sputnik episode of the 1950's and we expect more as schools gain experience with the "modern" approaches, as more teachers are trained in these approaches, and as a larger number of schools obtain the facilities necessary to fully implement these programs. Thus, we assume that undergraduate curricula should be built for students who have had the equivalent of a BSCS biology program in high school. We also assume that the entering students will have had three or more years of secondary level mathematics emphasizing a "modern" approach. We believe that these are appropriate assumptions in spite of the fact that we expect a return to somewhat greater emphasis on English, social sciences and humanities as elementary and secondary school curricula are re-evaluated in the late 1960's and 1970's.

We also assume that elementary and secondary schools will continue to vary widely with respect to the quality of education imparted. This variation in educational background may call for special adjustments in the colleges and universities. The most likely assumption is that the colleges and universities will expect students to meet certain standards before they are permitted to progress through an established curriculum. This may require additional emphasis on testing and the availability of either "remedial" facilities or advanced placement. Therefore, students from the less advanced secondary schools may need additional terms to complete the requirements of a particular curriculum.

THE FUTURE AGRICULTURAL SOCIAL SCIENTIST AND HIS EDUCATION

Since we assume that the administrative organization of the College of Agriculture is likely to change in the future, we prefer to discuss the agricultural social science student without reference to departmental affiliations. Within the broader agricultural social science area, two fairly distinct sub-specializations are evident. The first is the rural sociologist who is concerned primarily with the behavior of people in and from rural environments. The second is the closely related grouping of agricultural and forest economists, administrators and business managers who are more directly involved with the economic activities of production, processing and distribution of biologically derived commodities and related services.

The biological projection process with which the latter group is concerned could, in economists' jargon, be described as the "biological production function." This production can be characterized as aggregate growth of plant and animal organisms which have economic value. Food and industrial fibre are the most important, but not the only, components of this aggregate. Man can partially control this production process by manipulating the size, structure, genetic content and, perhaps, the environment of the biological community. The application of economics and management principles to the biological production process assists in making decisions regarding manipulations of biological production.

Effective managerial decisions and efficient economic organization of production from a biological base requires more than a casual comprehension of biological processes and the nature of biological organisms. A fundamental characteristic of the agricultural social scientist is his depth of understanding of the biological production process as well as his understanding of the social sciences. He is, therefore, an interdisciplinary oriented person.

We believe the student should have an appreciation of methods of acquiring and developing knowledge in, as well as acquaintance with, the major concepts in all important fields of study. By fields of study, we mean areas such as the physical sciences, the biological sciences, the communication arts, the fine arts, the social sciences and the humanities. Because of the increased emphasis on international activities on the part of our graduates and because of the shrinking size of the world in terms of communication time, we would suggest that most schools suffer because general education is viewed exclusively through the eyes of Western man. We, therefore, suggest that colleges and universities consider additional emphasis on non-Western oriented general education not to replace, but to complement and supplement the present Western orientation. But this report is not the place to discuss general education; therefore, these comments will not be developed in detail.

Students majoring in agricultural social science are preparing for careers emphasizing the solution of problems faced by agriculturally oriented people. At present, a high percentage of our graduates enter the business world, primarily in the field of agribusiness. A sizeable number enter public service in the fields of education, communication, natural resource development, regulatory agencies, public relations, trade associations and the rapidly expanding area of international agriculture. A smaller but still significant number become farmers or ranchers.

In the future, we expect an increasing percentage of our students will enroll in formal graduate or professional education beyond the bachelors degree. Future career choices will involve an increased number of graduates in international agriculture and farming and ranching but agriculturally related businesses are likely to employ the largest group. Domestic public service will likely demand about the same number as at present. International agriculture will probably not require a large number of B.S. graduates but a substantial number of those who obtain advanced degrees will be working overseas. Farming and ranching will likely require more graduates because the large scale farm business of the future will require well trained managerial talent. Because agricultural social science stresses both the production and

marketing aspects of agriculture and also both the biological and the social aspects, it will likely service an increasing proportion of those who plan farming or ranching as a life's work.

While the types of jobs typically chosen by our graduates may change little, the nature of their duties may change markedly. Many of the products that will be used by the farmer of the 21st century are still unknown. Many of the farm products that consumers of the 21st centruy will use are still unknown. Many of the institutional arrangements under which our economy and society will operate have not yet been seriously discussed. We are thus faced with the challenge of preparing students for a career in a world of uncertain change. Such a preparation must emphasize both learning to learn and the structure of principles about which future learning can be organized. It is in this spirit that we make recommendations regarding biology and related sciences in the following sections of the report.

BIOLOGICAL SCIENCE NEEDS

A common element for all agricultural social science students is the emphasis on integration of biology with economics and other social sciences in order to improve decision making. With this basic framework in mind, we suggest the following guidelines for the development of biological science courses appropriate for agricultural social science students.

First, we believe that the basic concepts of the scientific method underlying biology should be an important component of biological education. Included would be the concepts of stages in the evolution of a scientific discipline, the nature of a scientific theory, concepts common to many scientific fields (e.g., feedback and equilibrium), the role of hypotheses in science, basic methods of testing hypotheses, the role of quantification, the problem of choosing among yet untested hypotheses, and the evaluation of scientific theories.* These concepts can be taught in either (or both) of two ways. Courses in scientific methodology can discuss these concepts on a philosophical basis as they might apply in any scientific discipline. Or, courses in each of the disciplines can explicitly integrate scientific methodology with the science. The choice of approach will depend on the particular faculty environment.

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* A formal course proposal prepared by Dr. Herrman is attached as Appendix A to give an example of how such a set of concepts might be organized into a course. This particular outline may be too advanced for most freshmen and sophomores, but we believe that it warrants further study.

To provide an organized focus for our content recommendations with regard to biology, we suggest reference to Figure 1. This particular framework contains no reference to specific courses. Our recommendations likewise refer to content emphasis rather than course organization.

Within biology our recommendations can be summarized with reference to each dimension in Figure 1. Primary attention should be focused:

1. On the theme of organism and environment; (Secondary emphasis would be placed on the areas of behavior. Other themes would be discussed as they relate to developing an understanding of the primary and secondary theme. Note that the theme of science as inquiry has been separated out for special attention in a preceding paragraph.)

2. On individuals, populations and communities with relatively less emphasis on the world biome and minimal emphasis on the molecular, cellular and tissue-organ levels.

3. On economic plants, animals and protists as opposed to non-economic organisms. Man should receive particular attention.

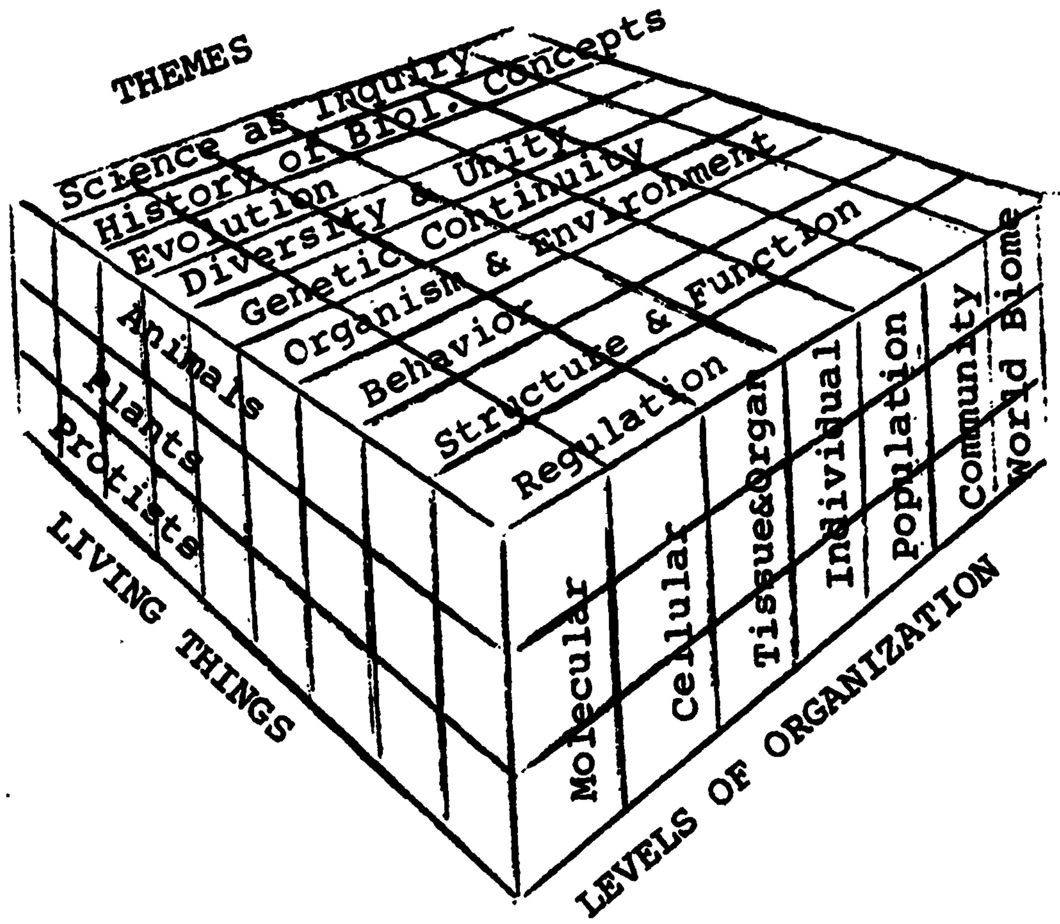
Our recommendations give primary emphasis to the theme concerning organism-environment relations--an area often labeled as ecology. We believe that it is in this context that our students can best grasp an understanding of the biological production function which is crucial to their functioning as agricultural social scientists. Both "basic" and "applied" biology courses should contribute to an understanding of this theme. Therefore, an ecological approach might be used in most, if not all, biology courses.

Specific content areas that should be discussed include such things as the concept of productivity, concept of an ecosystem, biogeochemical cycles, energy exchange and flow in ecosystems, food chains, concept of habitat and ecological niche, biological limiting factors, physical limiting facts, population energy flows, population structures, density effects, rates of growth and death, inter-actions among species, ecological dominance, succession and stratification. These concepts should provide an understanding in reasonable depth of the aggregate production function. Energy relations provide a useful focal point for organizing these concepts. Many of the concepts now emphasized in nutrition are subsumed in the series of concepts outlined here.

Secondary emphasis is given to the theme of behavior or, more specifically, the biological basis for behavior. Agricultural social scientists are especially interested in man's behavior since they must take it into account as well as try to influence it. Thus, many of the applications might be to man although other biological organisms deserve some attention. Concepts that should be discussed include effector-reactor relations, inherited behavioral tendencies, growth patterns, endocrine-behavior patterns, stimulus-response learning concepts, reflexes, conditional reflexes, habit,

Figure 1

Organization of Biology*



* Reproduced from <u>BSCS Material for Preparation of In-Service Teachers of Biology</u>, edited by T. F. Andrews, Biological Science Curriculum Study Special Publication No. 3, Boulder Colorado, 1964

drives, biological basis for adaptive behavior, sensory processes, motivation, effects of prenatal environment, deviant behavior, and psychoses. Whether these concepts are taught in "psychology" or "biology" is not our concern. We merely emphasize their importance.

Other themes in biology are less important to the agricultural social scientist. We have not attempted to assign priorities to the remaining themes because in total they are less important than the theme of organism and environment and no more important than the behavior theme. However, we will specify some important concepts from these themes because the agricultural social scientist should understand these concepts. Some of these concepts are already implicitly included in the primary and secondary themes. Others may require separate treatment.

Under the theme of unity and diversity, we would emphasize the need for clarifying patterns of consistency among biological organisms. This consistency is probably greatest at the molecular level. But, we would emphasize these patterns at the organism, population and community level. In understanding these patterns of consistency, one can also acquire knowledge of diversity of type in living organisms. This study of unity and diversity also provides opportunity for the study of such subjects as the mechanisms of adaptation through natural selection and of mutation. The study of unity-diversity considerations also brings to the fore the principles and purposes of classification. Classes might be illustrated where possible with economically significant plants and animals, but the teacher should not force memorization of the classification of any particular plant or animal. The emphasis should be on the principles and purposes of classification and would include the bases of classification. This treatment of classification would require but a small part of a course. The emphasis should be on patterns of unity and diversity in structure and behavior that will be useful to the student in interpreting the applicability of future developments in biology as well as in transferring biological knowledge from one environment (such as the United States) to another (such as Africa).

The themes of regulation and homeostasis are of particular relevance in both biological and social sciences. Because of the dual nature of these concepts, the two fields of study should reinforce each other. Biologists may have a better understanding of dynamic processes than do the social scientists. Therefore, an understanding of basic concepts in this area may help one become a better social scientist. Important concepts in this area include feedback, adaptation of structure, adaptation of function, adjustment paths, succession, symbioses and competition. We emphasize that these concepts should be treated with reference to the organism, population and community level with primary emphasis on the population and community levels. We recognize that the concepts are often taught with reference to the organism or even sub-organism level, but we are less interested in these applications.

The basic concepts of genetic theory are included under the heading of genetic continuity and inheritance. Important concepts in this area include the chemical basis for inheritance, chromosome theory, mitosis, meiosis, gene structure, gene function, mutation, chromosome linkage and cross-over, dominance, recessiveness, sexual and asexual life cycles, natural selection, eugenics and evolution, and random effects. Population genetics is an appropriate organizational focus for this course. Adequate time should be devoted to human genetics and the relation of human genetics to the biological basis of behavior.

Evolution is a theme that is hard to define separately since evolution is closely related to concepts such as genetic continuity, homeostasis and organism-environment relations. Therefore, we expect that evolution will largely be treated as part of the other content areas. However, treatment of the dynamic process of evolution should be a part of the biological science program since it would help the student appreciate the process of economic evolution. An understanding of the evolutionary process also aids in analyzing the problems of developing and adapting biological organisms to new environments. Concepts that might be studied include theories of evolution, human evolution, population and community evolution processes, and succession. Historical detail is not important, but an understanding of the process should be stressed. Hopefully, the student can relate concepts of biological evolution to concepts of social evolution.

Some attention should be given to the interrelation of structure and function as a theme. Since our primary emphasis is on the individual, population and community levels, many of the important concepts relating to structure and function are of limited relevance. Yet the basic relations of structure and function should be studied along with concepts of adaptation, evolution of structure and function relationships over time, and related ideas. A basic knowledge of these concepts is necessary to understand the organism, population and community relations that we consider important.

We recommend minimal emphasis on historical evolution of biological concepts. Students must appreciate the changing nature of biological science and understand the possible implications for further revisions and changes. Beyond that, we see little value in studying this area.

Emphasis should be placed on economic plants, animals and protists since the agricultural social scientist is primarily concerned with decisions involving these specimens. Man is, of course, the primary focal point for the agricultural social scientist and should receive considerable attention. But, man lives by using economic organisms, and he must understand their biological processes. Note that we include in the economic organism category not only those items which commend a price <u>per se</u>, but also non-market items that are highly valued such as wildlife or natural beauty.

We stress studying biology at the individual, population and community level because most agricultural social scientists are involved with problems at these levels. The biologist must understand why an animal reacts in a specified manner when injected with a hormone. The agricultural social scientist is primarily concerned with how the individual reacted and the implications of this reaction for making decisions regarding use of the hormone. He is not seriously concerned with the particular cellular or molecular reactions except as they result in an effect on the animal. We recommend less attention for the world biome because the present state of knowledge implies a greater difficulty in achieving useful concepts. This is an important area which should receive additional emphasis as biologists achieve a simplification and understanding of the relationships.

We have mixed reactions regarding the desirability of laboratories as part of the education in biological sciences. In general, we see little or no benefit for the agricultural social scientist in learning laboratory techniques. But, if the laboratory experience is an efficient way of teaching concepts and principles, we are in favor of it. Demonstrations might be considered as a substitute for laboratories. The demonstration technique may often permit the students to observe and learn the basic concepts in less time and at lower cost than would be possible with laboratories.

Students preparing for Ph.D. level training should get the same basic understanding of biology at the undergraduate level as the terminal B.S. or M.S. student in the agricultural social sciences. Students specializing in farm management or agri-business might place greater emphasis on genetics and the nutritional aspects of the organism. Students specializing in rural sociology or agricultural administration may give greater emphasis to the behavioral aspects of biology especially as they relate to human behavior. On the other hand, the similarities of agricultural social science students probably outweigh their differences. We hope that special courses will not be needed to service agricultural social science students. Separate courses to "service" special groups of students have traditionally degenerated into second-rate courses--we can not afford second-rate courses for our majors. We believe that the emphasis on ecology and behavior in the basic biology program could well serve all students in agriculture and, possibly, biological science. Students whose specialized area is either biology or applied biology would, of course, need additional courses emphasizing biological concepts at the sub-organism level and giving greater attention to the themes that we have de-emphasized.

To restate our position, we recommend a biological science program with emphasis on the individual, population and community levels of organization. Sufficient attention should be given to other levels to permit understanding the desired levels. We are primarily concerned with economic plants and animals, with man being the social scientist's focal point. Most content areas of biology have relevance to the agricultural social scientist. But, primary emphasis should be given to the general areas of organism-environment relations and the biological basis for behavior.

PHYSICAL SCIENCES NEEDS

Our recommendations here are divided into three areas--mathematics (and statistics), chemistry and physics. We would hope that mathematics and chemistry might parallel biology and would prefer that they precede rather than follow biology. Use of college chemistry and mathematics permits a more quantitative orientation in biology and allows integration of biochemistry with biology.

Mathematics

One of the distinguishing features of agricultural social scientists has been their interest in quantification. Quantification is an important aid to decision making. We have reviewed the studies of undergraduate mathematics education prepared by the Committee on the Undergraduate Program in Mathematics and make our basic recommendations consistent with the course pattern they have recommended.* We believe that Mathematics 1 and 2P are the absolute minimum for all B.S. candidates in agricultural social science. These courses presume that students have an understanding of what is now called college algebra when they complete high school. Students preparing for Ph.D. level work should be strongly encouraged to complete additional mathematics at the undergraduate lev .l. Other students might be advised to study additional mathematics or statistics.

Mathematics 1 and 2P can be briefly outlined as follows:

Mathematics 1. Introductory Calculus. (3 or 4 semester hours)

The purpose of this course is to introduce the ideas of derivatives and integrals with their principal interpretations and interrelations and to develop the simpler techniques of differentiation and integration for the elementary functions.

The integral and derivative. (6 lessons)
Differential calculus of polynomials and rational functions. (9 lessons)
Antiderivatives and integrals of polynomials. (8 lessons)
Logarithms and expoentials. (6 lessons)
Calculus in Euclidean geometry. (4 lessons)
Trigonometric functions. (6 lessons)

Mathematics 2P. Probability. (3 semester hours) Prerequisite: Mathematics 1

Probability as a mathematical system. (9 lessons)
Random variables and their distributions. (13 lessons)
Limit theorems. (4 lessons)

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* A General Curriculum in Mathematics for Colleges. 1965. Committee on the Undergraduate Program in Mathematics, P. O. Box 1024, Berkeley, California 94701.

Topics in statistical inference (7-13 lessons: amount of time devoted to this topic depends on time spent teaching mathematics in earlier sections of course).

Chemistry

Many of the developments in modern biology involve a chemical basis. Therefore, study of the basic concepts of organic chemistry is essential. Concepts or areas needing high priority include atomic structure, basic reactions, relations of density, volume, pressure and reactions, acid-base relations, catalysts, basic structure of organic compounds, basic laws of chemical combination, oxidation-reduction and matter-energy relations. The distinction between inorganic and organic chemistry appears of little real value. Many of the concepts normally included in inorganic chemistry would be taught in an organic chemistry framework. By teaching chemistry rather than inorganic and then organic, some efficiency could be achieved, and agricultural social science students might complete their chemistry requirement in less than one year. We do not consider a separate course in biochemistry essential. Needed concepts could easily be included in the usual one year chemistry course if the integrated approach is used or could be included in cell biology if the chemistry course is shortened to less than one year.

Our earlier comments regarding the role of laboratories and demonstrations in biological science apply also to chemistry.

Physics

Both modern and classical physics are relevant. Physics can serve two purposes--the need for a minimum understanding of the physical elements of the world in which we live and a greater appreciation of biological processes that involve a physical basis. Concepts that should be included are basic principles of heat, light and mechanics. We recommend less emphasis on physics than on mathematics and chemistry. These concepts may be taught in sufficient depth in a well-taught high school physics course supplemented by the college chemistry course or a college level general education course in physics.

SUMMARY

The specialization of an agricultural social scientist focuses on those social and economic problems associated with <u>rural</u> areas and the production, processing and distribution of <u>biologically</u> derived commodities and related services. Two fairly distinct groups of sub-specialists are evident. The first is the rural sociologist who is concerned primarily with the behavior of people in and from rural environments. The second is the closely related grouping of agricultural and forest economists, administrators and business managers who are more directly involved with the economic activities of production, processing and distribution of biologically derived commodities and related services.

Our recommendations recognize a world of continuing and uncertain change. The occupational classifications of specialists in our area may change little during the next 30 to 50 years. But, the nature of their duties may change markedly. New products and inputs will be developed. New institutional arrangements will be developed. Indeed, the organization of our Colleges of Agriculture may change markedly. In view of this challenge, we argue that University level education must emphasize learning to learn as well as the development of a structure of principles about which future learning can be organized.

Effective managerial decisions and efficient economic organization of production from a biological base requires more than a casual comprehension of biological processes and the nature of biological production process as well as his understanding of the social sciences. He is, therefore, an interdisciplinary oriented person who emphasizes the integration of biology with economics and other social sciences in order to improve decision making.

We believe that the basic concepts of the scientific method underlying biology should be an important component of biological education. Our recommendations with regard to the substantive content give primary emphasis to the theme concerning organism-environment relations--an area often labeled as ecology. We believe that our students can best understand the biological production function, which is crucial to their functioning as an agricultural social scientist, if an ecological approach is used. Both "basic" and "applied" biology courses should contribute to an understanding of this theme. Secondary emphasis is given to the theme of behavior or, more specifically, the biological basis for behavior. Agricultural social scientists are especially interested in man's behavior since they must take it into account as well as try to influence it.

Other themes in biology are less important to the agricultural social scientist. We have not attempted to assign priorities to the other themes because in total they are less important than the theme of organism and environment and no more important than the behavior theme.

Applications and illustrations should emphasize economic plants, animals and protists since the agricultural social scientist is primarily concerned with decisions regarding these specimens. Man is, of course, the primary focal point for the agricultural social scientist and should receive considerable attention. Included in our definition of economic plants, animals and protists are not only those items which command a price <u>per se</u>, but also non market items that are highly valued, such as wildlife, natural beauty, etc.

We emphasize the study of biology at the individual, population and community level because most agricultural social scientists are involved with problems at these levels. Biologists must understand why an animal reacts in a specified manner when injected with a hormone. The agricultural social scientist is primarily concerned with how the animal reacted and the implications of this reaction for making decisions regarding use of the hormone. He is not seriously concerned with the particular cellular or molecular reactions except as they result in an effect on the animal.

We have mixed reactions regarding the desirability of laboratories as part of the education in the biological and physical sciences. Laboratories and demonstrations must be evaluated to determine if they are an efficient way of teaching concepts and principles or if they merely serve to develop techniques.

Our minimum recommendations in mathematics involve understanding the basic concepts of calculus and probability-statistics. These amount to about six or eight semester credits of mathematics and/or statistics beyond the "College Algebra" level which is assumed for University admission. The recommended chemistry could be taught in the same or fewer credits if a chemistry sequence integrating organic and inorganic is developed. The needed physics can, we believe, be obtained from a "general education" course.

October, 1967
scm

APPENDIX A

INTRODUCTION TO SCIENTIFIC THOUGHT AND INQUIRY

With the development of an increasing body of principles and theory in the biological sciences, the common features of all scientific theories and empirical activity become increasingly evident. It appears that undergraduate students would benefit from having these common features pointed out at an early stage in their college careers, perhaps at the sophomore level. Discussion of the nature of all theories should make it easier for students to learn the particular theories of different scientific disciplines. In addition, a clearer understanding of experimental and research procedures should provide students with a better understanding of how scientific knowledge is produced and the way in which new knowledge replaces old.

The proposed course goes beyond the usual scope of a philosophy of science course. In addition to considering scientific theory and method, the proposed course also considers the problems involved in making empirical tests of hypotheses derived from theories. The latter portion of the course is, in effect, a generalization of material which often is not presented to students until they take a "methodology" course in their first year of graduate school. The usual philosophy of science course, focussed as it is on scientific theory, often seems to suggest that no particular problems are involved in constructing testable hypotheses or in developing means to test them. Such an approach is likely to leave students with the idea that scientific research is a rather mechanical process and gives them little appreciation of the creative aspects of research. The proposed course would remedy this by emphasizing both the theoretical and the empirical aspects of scientific activity.

An outline of the proposed course follows:

<u>Introduction</u>

- What is "science"?
- The scientific method
- The stages in the development of scientific theories
  - Description
  - Classification
  - Intuitive theories
  - Experimental theories

<u>The Nature and Construction of Scientific Theory</u>

- Types of theories
  - Scientific theories--produce testable hypotheses
  - Non-scientific theories--do not produce testable hypotheses, e.g., metaphysics
- The structure of theories
- Symbolic thinking

Appendix A

Scientific Theories as Theories of Systems

- Components of the system
  - Definition and classification
  - Observability
    - Observable components--e.g., price, light rays, I.Q. scores
    - Unobservable components--e.g., utility, electron, id, intelligence
  - Rules governing the behavior of the components
    - Formal theories--axioms
    - Empirical theories--laws developed through experimentation

- System states and responses
  - System states
    - Equilibrium
    - Disequilibrium
  - Communication or interaction within the system
    - Stimuli--internal and external sources
    - Responses
      - Reaction threshold
      - Response probabilities--probabilistic systems
      - Magnitude of response or change
      - Rate of response or change
    - Feedback

- Changes over time in the system
  - System state
    - Moving equilibrium
    - Disequilibrium
  - Development--developmental stages, growth, specialization
  - Reproduction
  - Dissolution

The Testing of Scientific Hypotheses

- The development of testable hypotheses from scientific theory
  - Tests depend upon observable phenomena
    - Tests of relationships between observable phenomena
    - Tests concerning unobservable phenomena based on observations of observable phenomena
  - Quantification--the assignment of numerical values to scientific phenomena
    - Measurement
    - The Heisenberg Principle
  - Assumptions about the mathematical form of the relationships between variables
  - Formulation of techniques to estimate these relationships

Appendix A

Empirical tests of hypotheses
    Estimation oı the relationship between variables
    Evidence which warrants the acceptance or rejection of hypotheses
        Statistical tests of the significance of relationships
        Judgments of accuracy required for tests of hypotheses

The Evaluation of Scientific Theories

Criteria which have been employed in the evaluation of theories
    Realism of assumptions
    Predictive power
    Simplicity
Judgment of a theory on the basis of hypotheses derived from it

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